Reprint from
SURGERY, *Gynecology & Obstetrics*
August, 1957, Vol. 105, 129–135

RESECTION AND HOMOGRAFT REPLACEMENT OF INNOMINATE AND CAROTID ARTERIES WITH USE OF SHUNT TO MAINTAIN CIRCULATION

MICHAEL E. DE BAKEY, M.D., F.A.C.S., and E. STANLEY CRAWFORD, M.D.,
Houston, Texas

ANEURYSM, tumor, arteriovenous fistula, and arteriosclerotic occlusion occasionally involve the innominate and carotid arteries. Excisional therapy of these lesions in other arteries of this size is ordinarily accomplished with technical ease and with no significant physiologic disturbances. Similar surgical treatment of such lesions involving the innominate or carotid arteries, however, imposes special problems owing to several factors relating particularly to their location and to their vital function in supplying blood to the brain. For one thing, the innominate and the first portion of the carotid arteries lie within the thorax and its cervical outlet and their adequate exposure requires a combined approach through the chest and neck. For another, the necessity for temporary arrest of circulation through these vessels during performance of the procedure even for brief periods may produce serious ischemic damage to the brain, which is one of the most sensitive organs to acute anoxia. For these reasons the surgical management of fusiform aneurysms of these arteries assumes particular significance. Accordingly, this report is concerned with a consideration of this problem and the presentation of a case illustrating the successful application of a method of surgical management of such aneurysms.

From the Cora and Webb Mading Department of Surgery, Baylor University College of Medicine, and the surgical service of the Methodist Hospital, Houston, Texas.

REPORT OF CASE

B. R. F., a woman 64 years old, was admitted to the Methodist Hospital, Houston, Texas, June 24, 1956, with the chief complaint of a painful mass in the right supraclavicular region which was first noted as an asymptomatic pulsatile mass after the patient was involved in an automobile accident in 1949. No change was detected in the mass until June 1955, when it became painful and progressively larger.

Examination on admission revealed an oval pulsatile tumor, measuring 5 by 10 centimeters, lying just superior to the right sternoclavicular joint and extending down into the mediastinum. It was slightly tender and moderately mobile. Pulsations in the right arm and carotid artery above the lesion were normal. The blood pressure was 130 millimeters of mercury systolic and 80 millimeters of mercury diastolic. Results of the serologic test for syphilis were negative and routine examination of the blood and urine

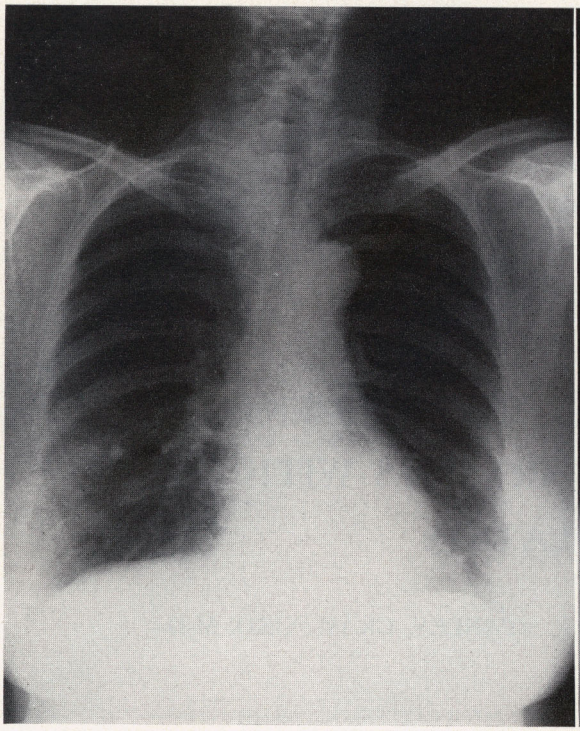

FIG. 1.

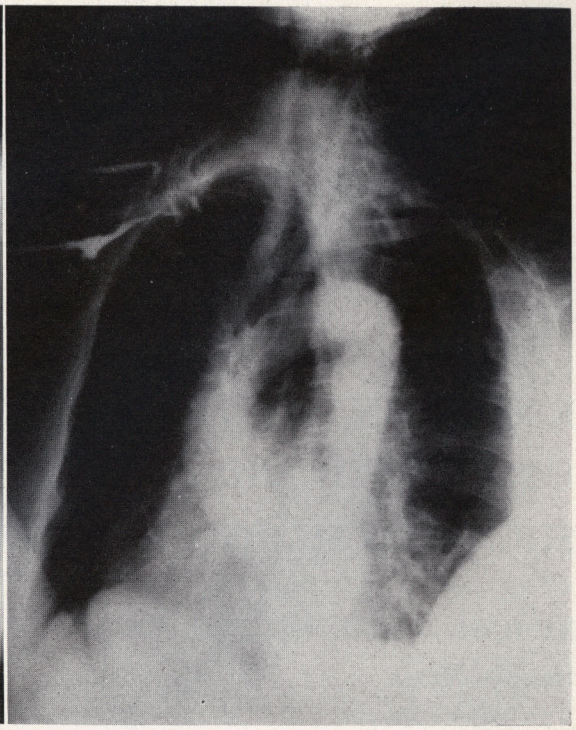

FIG. 2.

FIG. 1. Roentgenogram of chest showing widening of superior mediastinal shadow to right and slight displacement of trachea to left.

FIG. 2. Angiocardiogram demonstrating aneurysm of innominate and carotid arteries at thoracic outlet.

yielded normal results. Roentgenograms of the chest showed a rounded expansion of the upper portion of the mediastinum to the right with slight displacement of the trachea to the left (Fig. 1). A partially thrombosed, nodular, fusiform aneurysm in the thoracic and lower cervical portions of the right common carotid and innominate arteries was demonstrated angiographically (Fig. 2).

Operation was performed on June 29, 1956, under general anesthesia. Excellent exposure of the aorta, innominate, subclavian, and carotid arteries was obtained through a cervicothoracic incision that began in the neck anterior to the sternocleidomastoid muscle just below its insertion onto the mastoid process and extended anteriorly and medially over the suprasternal notch. The incision was continued downward in the midline over the sternum to a point opposite the second intercostal space where it was curved toward the right to follow this space to the anterior axillary line (Fig. 3). Entrance to the chest was obtained through the second intercostal space; the sternum was split from the second interspace to the suprasternal notch. By proper retraction and dissection of the mediastinum and deep cervical regions the exposure was completed revealing the aneurysm to involve the common carotid, subclavian, and innominate arteries at the bifurcation of the innominate artery (Figs. 4 and 5).

The innominate artery proximal to the aneurysm, as well as the right common carotid and right subclavian arteries distal to it, was mobilized. The subclavian artery was divided between a distal temporary clamp and a proximal ligature. Specially designed partially occluding clamps were then applied to the innominate and carotid arteries above and below the aneurysm. Longitudinal incisions were made into the excluded segments of the arteries, and a specially designed shunt was inserted into both openings above and below the aneurysm (Figs. 6 to 8). The aneurysm was then excised and replaced by a reconstituted, lyophilized bifurcation iliac homograft anastomosed proximally to the innominate artery and distally to the subclavian and common carotid arteries. The lateral occluding clamps were reapplied as the cannulas were removed, and the arteriotomies were repaired with continuous No. 5-0 arterial silk sutures (Fig. 9). Removal of the aneurysm and its replacement with a graft required 45 minutes, but by use of the shunt and the technique described for its insertion, cerebral circulation was maintained during this time.

The wound was closed in the conventional manner, and immediately after operation normal pulses were palpable in the right carotid and subclavian arteries. Postoperative convalescence was uneventful and at no time did the patient show signs of neurologic disturbances. Peripheral pulses remained normal, and an angiocardiogram made July 14, 1956, the day before the patient's discharge from the hospital, revealed a normal reconstructed innominate, carotid, and subclavian arterial system (Fig. 10). On gross and microscopic examination of resected specimen the typical changes of an arteriosclerotic aneurysm were observed.

At this writing, 8 months postoperatively, the patient's health continues to be good, and she has normal peripheral pulses and no signs of operative complications.

DISCUSSION

Although trauma may have played some role in the development of this aneurysm, the underlying pathologic features were characteristic of arteriosclerosis. Operation was indicated because of pain and progressive enlargement leading to the likelihood of development of such complications as rupture, hemorrhage, thrombosis, pressure upon adjacent structures, and death.

In the successful application of excision and graft replacement therapy in this case, there are two factors that deserve special consideration. The first is concerned with proper exposure of the lesion and the second with prevention of ischemic damage to the brain during performance of the procedure. In dealing with aneurysms arising in the major tributaries of the aortic arch, adequate exposure is essential in order to secure control of these vessels and to provide accurate definition of the lesion. Various methods of operative exposure of the blood vessels in the superior mediastinum have been developed, and these have been reviewed in recent publications by Cooley and De Bakey (2) Elkin, Shumacker, and Wilson and Carr. In our experience the combined cervicothoracic approach without clavicular removal, as proposed by Churchill for neoplastic lesions and employed in the case reported herein, has been found the most satisfactory for this purpose. It has the advantage of providing

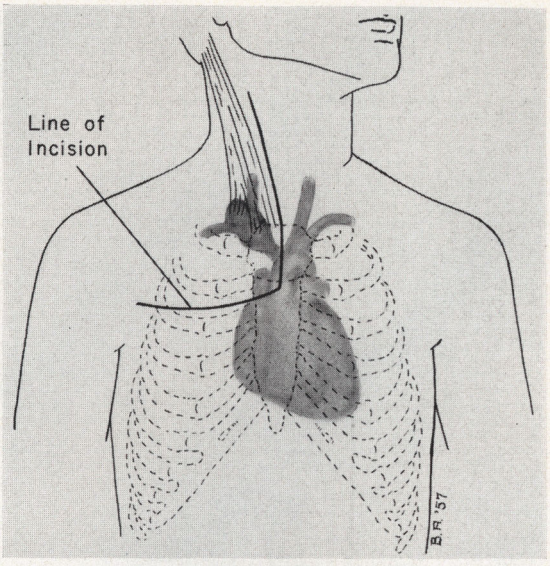

FIG. 3. Diagram of neck, chest, heart, and great vessels illustrating position of incision and its relationship to these structures.

direct and generous accessibility to the arteries both proximal and distal to the aneurysm, thus permitting safe control of these vessels as well as facility in use of a shunt. Moreover, it provides stable wound repair with complete restoration to normal of the anatomic and functional relationships in the neck and thorax, thus minimizing postoperative pulmonary disturbances.

The second and more important consideration in excisional therapy of diseases of the innominate and carotid arteries is concerned with the prevention of ischemic damage to the brain following arrest of circulation through these vessels. Although the reported incidence of such complication following ligation of the carotid artery has been somewhat variable, it is generally agreed to be relatively high with figures ranging between 25 and 70 per cent. A relatively high incidence of such complications has also been observed even after temporary interruption of circulation through these vessels. This is well demonstrated by the occurrence of transient or permanent neurologic changes in 4 of 7 recently reported cases of aneurysm or injury of the innominate or common carotid arteries treated by

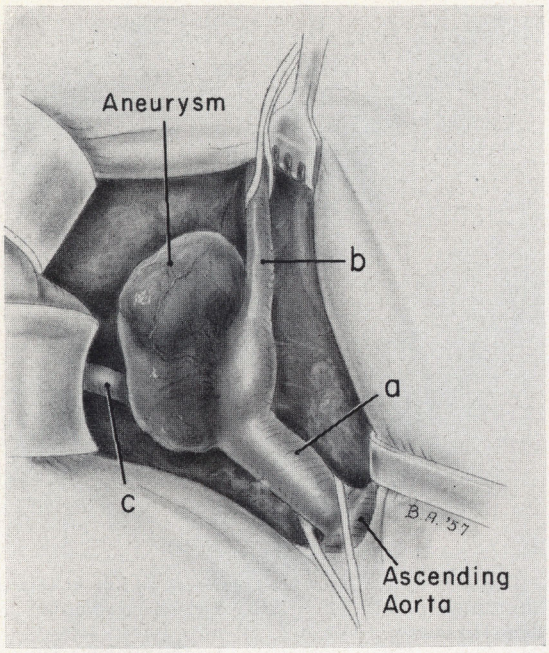

FIG. 4.

FIG. 4. Drawing showing fusiform aneurysm involving (*a*) innominate, (*b*) right common carotid, and (*c*) right subclavian arteries.

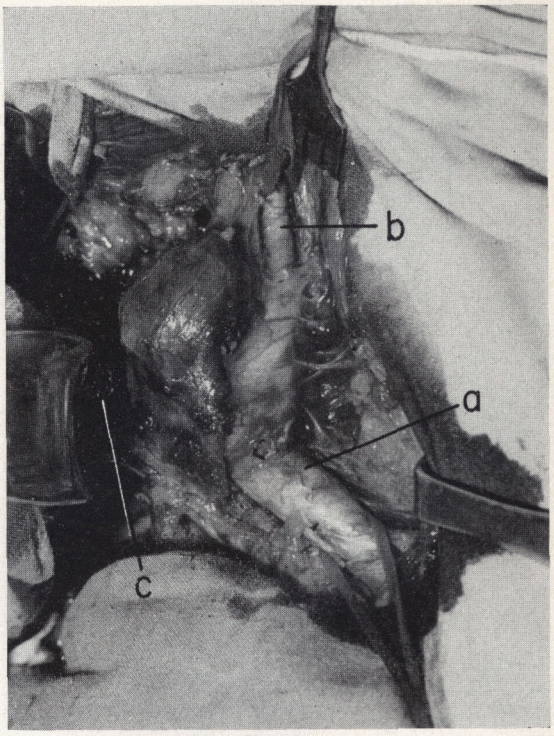

FIG. 5.

FIG. 5. Photograph taken at operation showing fusiform aneurysm arising in distal part of (*a*) innominate artery and involving proximal segments of (*b*) right common carotid and (*c*) right subclavian arteries.

resection and restoration of arterial continuity. Of particular significance is the fact that there was no correlation between the duration of the period of arrest of circulation in these cases and the occurrence of neurologic disturbances. Whereas, for example, manifestations of transient or permanent ischemic damage to the brain occurred in 3 of these cases following periods of carotid occlusion of 21, 57, and 65 minutes respectively, no such changes occurred in 3 other cases following periods of 19, 60, and 67 minutes respectively. Even in the case reported by Mahorner and Spencer, who used a two stage operation with insertion of a homograft to by-pass the aneurysm of the innominate artery during the first stage and resection of the aneurysm at the second stage approximately 7½ months later, partial hemiplegia occurred presumably from brief periods of cerebral ischemia resulting from traction and kinking of the by-pass homograft during mobilization and resection of the aneurysm.

This variability in the tolerance of the brain to different periods of carotid occlusion has long been recognized and apparently is dependent upon a number of factors including age, nature of the lesion, and particularly development of adequate collateral circulation. Various methods for determining preoperatively the adequacy of collateral circulation have been proposed and these have been reviewed by Kirby, Johnson, and Donald. None of these tests, however, has proved entirely reliable, as exemplified by the occurrence of hemiplegia after the test had indicated an adequate collateral circulation. Similarly, various methods of increasing collateral circulation have been proposed, but these too have not been found entirely dependable.

In light of these considerations and particularly in view of the unpredictable but

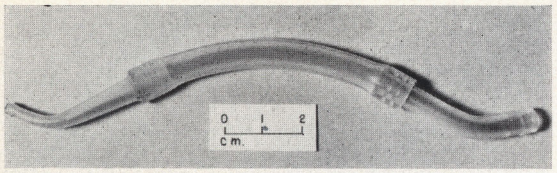

FIG. 6.

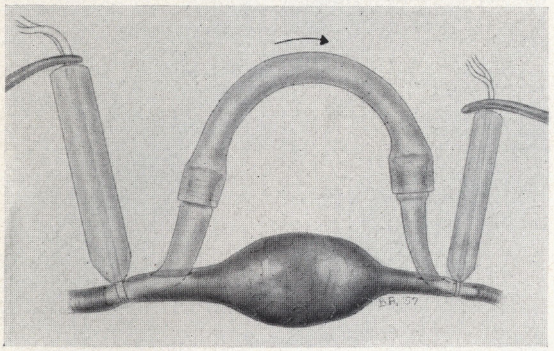

FIG. 7.

FIG. 6. Photograph showing shunt made of tygon tubing and two tooled lucite cannulas.

FIG. 7. Drawing illustrating method of applying shunt to by-pass aneurysm.

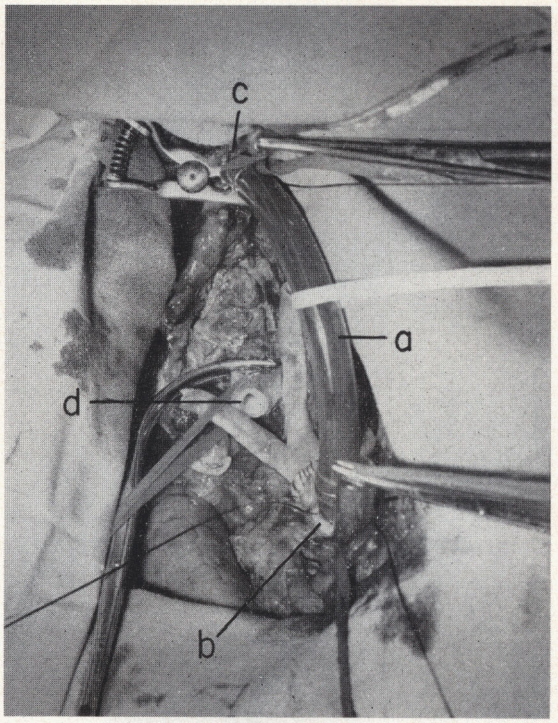

FIG. 8.

FIG. 8. Photograph taken during operation showing (*a*) shunt functioning and providing circulation from (*b*) innominate artery to (*c*) common carotid artery. The anastomosis of the bifurcation homograft to the innominate artery has been completed, and the anastomoses of the two links of the graft to the (*c*) common carotid and (*d*) the subclavian artery remain to be performed.

frequent occurrence of ischemic brain damage following excisional therapy of lesions of the innominate and carotid arteries, it would appear highly desirable to employ methods that provide effective protection against the development of such complications both during and after operation. Obviously, restoration of arterial continuity by end-to-end anastomosis or by use of a suitable graft to insure maintenance of normal cerebral circulation after operation is the procedure of choice. For protection of the brain against ischemic damage consequent to temporary arrest of innominate or carotid circulation during performance of this procedure, two methods have been proposed, namely hypothermia and the use of a temporary shunt (8). The former method, by reducing the metabolic rate and oxygen demand of the tissues, would appear to be a satisfactory method for this purpose according to certain clinical and experimental observations. On the basis of our clinical experience as well as that of others, however, hypothermia has not always prevented ischemic damage to the central nervous system following temporary arrest of the circulation to this organ. For this reason and because of certain other disadvantages in the use of hypothermia, we believe that the use of a temporary shunt is the preferable method.

The maintenance of normal cerebral circulation during as well as after operation is considered the most effective solution to this problem. The method used in the case reported herein to maintain circulation through the carotid artery during operation was developed in our laboratory by Soltero and Greenberg. These investigators found that this shunt, consisting of a segment of tygon tubing with lucite cannulas at each end, could be rapidly inserted into the carotid artery of a dog and would provide rela-

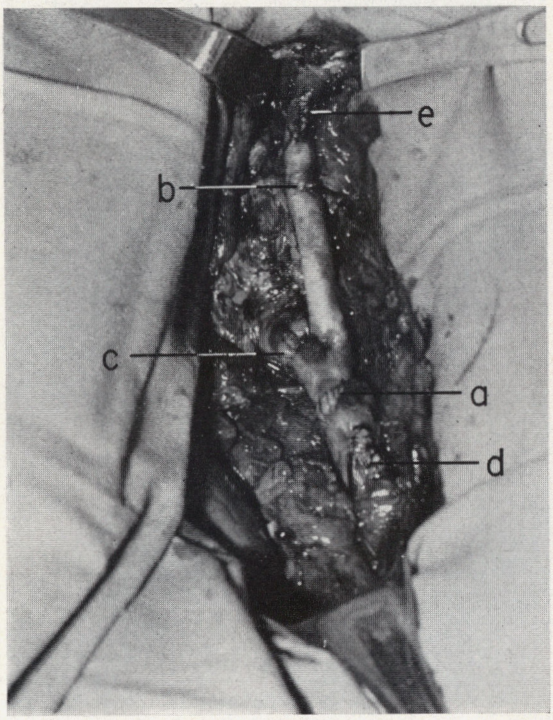

FIG. 9.

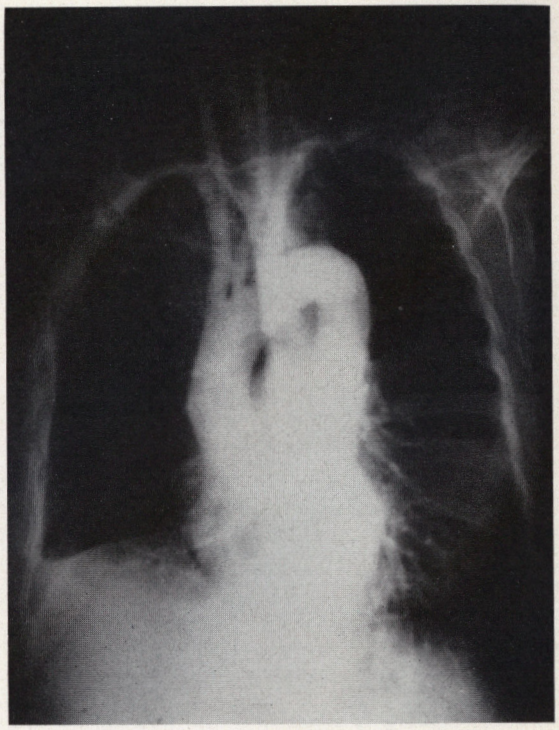

FIG. 10.

FIG. 9. Photograph taken at operation showing completed anastomoses of homograft to (*a*) innominate, (*b*) common carotid, and (*c*) subclavian arteries. The repaired arteriotomy incisions representing sites of insertion of shunt may be observed in (*d*) innominate and (*e*) common carotid arteries.

FIG. 10. Postoperative angiocardiogram showing normal restoration of circulation in innominate, common carotid, and right subclavian arteries.

tively normal circulation in the artery distal to the point of occlusion as evidenced by pressure determinations in this segment of the vessel. Clinically, it has been found equally effective for this purpose not only in our experience but also in its application to a case of incomplete arteriosclerotic occlusive disease of the common carotid artery. In this connection it is of interest to observe that in the latter case the shunt used by Cooley and his associates utilized a 14 and 16 gauge needle on each end of the polyvinyl tubing rather than the specially tooled lucite cannulas as employed in our case. This may be a significant factor in the occurrence of transient hemiplegia immediately after operation in their case since the blood flow through a 16 gauge needle is considerably less than that which may be obtained through the lucite cannulas employed in our case. The lumen of the latter is about twice the size of a 16 gauge needle. Accordingly, this method because of its simplicity of application and its efficacy in providing complete protection against ischemic damage to the brain during excisional therapy for diseases of the innominate and carotid arteries is considered the most satisfactory for this purpose.

SUMMARY

Excisional therapy, when applied to lesions of the innominate and carotid arteries, is frequently associated with neurologic sequelae resulting from cerebral ischemia that may occur either during or after operation. Such complications may be prevented by use of a procedure that both restores con-

tinuity of the blood vessel and protects the cerebrum during operation. Restoration of arterial continuity can be accomplished by end-to-end anastomosis of the patient's own artery after excision or by repair of the arterial defect with a suitable blood vessel substitute. By reducing the tissue metabolic requirements, hypothermia would theoretically protect the cerebrum during operation, but clinical experience indicates that it is not always effective, and it superimposes certain technical difficulties and complicating factors of its own.

A case has been reported in which an aneurysm of the innominate and carotid arteries was successfully removed. Development of neurologic deficits resulting from cerebral ischemia was prevented by maintenance of cerebral circulation during operation with a specially designed shunt that by-passed the field of operation. Normal circulation was permanently restored by insertion of a bifurcation homograft, which was anastomosed to the innominate artery proximally and to the carotid and subclavian arteries distally.

REFERENCES

1. CHURCHILL, E. D. Discussion of Taylor, G. W., and Wallace, R. H. Carcinoma of breast; 50 years' experience at Massachusetts General Hospital. Ann. Surg., 1950, 132: 833.
2. COOLEY, D. A., and DE BAKEY, M. E. A report on the surgical considerations of intrathoracic aneurysms of the aorta and great vessels. Ann. Surg., 1952, 135: 660.
3. COOLEY, D. A., AL-NAAMAN, Y. D., and CARTON, C. A. Surgical treatment of arteriosclerotic occlusion of common carotid artery. J. Neurosurg., 1956, 13: 500.
4. DE BAKEY, M. E., and COOLEY, D. A. Excisional therapy of aortic aneurysms. Am. Surgeon, 1953, 19: 603.
5. DE BAKEY, M. E., COOLEY, D. A., and CREECH, O., JR. Aneurysm of the aorta treated by resection, analysis of 313 cases. To be published. J. Am. M. Ass.
6. ELKIN, D. C. Exposure of blood vessels. J. Am. M. Ass., 1946, 132: 421.
7. KIRBY, C. K., JOHNSON, J., and DONALD, J. G. Aneurysm of the common carotid artery. Ann. Surg., 1949, 130: 913.
8. MAHORNER, H., and SPENCER, R. Shunt grafts; a method of replacing segments of the aorta and large vessels without interrupting the circulation. Ann. Surg., 1954, 139: 439.
9. PONTIUS, R. G., BLOODWELL, R. D., COOLEY, D. A., and DE BAKEY, M. E. The use of hypothermia in the prevention of brain damage following temporary arrest of cerebral circulation: experimental observations. Surgical Forum 1954; American College of Surgeons. Vol. V, p. 224. Philadelphia: W. B. Saunders Co., 1955.
10. SHUMACKER, H. B., JR. Operative exposure of the blood vessels in the superior anterior mediastinum. Ann. Surg., 1948, 127: 464.
11. SOLTERO, L. R., and GREENBERG, S. D. Report of a method for maintaining distal circulation in the carotid artery during arterial resection. To be published.
12. WILSON, H., and CARR, D. A report on the combined cervical and thoracic approach for resection of the large arteriovenous aneurysm. Surgery, 1948, 24: 342.